ECM ENGINE CONTROL AND MONITORING

AFM1040™/AFM1540™

Air-Fuel Ratio Combustion Monitor

Instruction Manual

02/06 Part Number 1040A-6

Printed in the United States of America.

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Introduction

The Air-Fuel Ratio Combustion Monitor (AFM1040/AFM1540)

The ECM Air-Fuel Ratio Combustion Monitor (AFM) was designed for the professional calibration of fuel-injection or carburetor systems. Using a state-of-the-art, broadband lambda (λ) sensor, the AFM provides unmatched measurement range, accuracy, and speed-of-response in a compact, lightweight package. Suitable for dynamometer or in-vehicle applications, the AFM is an essential tool for any engine development program.

AFM features:

- Measurement range of 8 to 18 AFR (gasoline[1])
- Easy calibration in air
- 0 to 5 volt linearized output for use with data acquisition or engine control systems
- SMB (Serial Measurement Bus) interface on AFM1540
- Can work with Bosch LSU 4.9, LSU 4.2, or NTK UEGO sensor (user-selectable only with AFM1540)
- 11 to 28 VDC operation[2]

AFM1040/AFM1540 Components List

The following items are included with an AFM1040 Kit:

Item No.	Description	Part Number
1.	Control Module (AFM1040)	1040A-1
2.	Lambda LSU 4.9 Sensor and	1049E-2a
	Sensor Adapter or	1049E-2b
	Lambda LSU 4.2 Sensor or	1042A-2
	NTK TL UEGO Sensor	1001A-2
3.	Wiring Harness, 6m or	1002A-3a[3]
	Wiring Harness, 3m or	1002A-3b[3]
	Wiring Harness, 1m	1002A-3c[3]
4.	Calibration Screwdriver	2400E-35
5.	Sensor Mounting Boss and Plug (M18X1.5mm)	1000A-5
6.	Instruction Manual	1040A-6

[1] Assumes fuel H:C ratio of 1.85. For other fuels see the "Fuel Type Compensation" section.
[2] An AC/DC Power Supply (P/N 1000A-7) is available.
[3] ECM offers custom harness solutions. Contact ECM for more information.

The following items are included with an AFM1540 Kit:

Item No.	Description	Part Number
1.	Control Module (AFM1540)	1540A-1
2.	Lambda LSU 4.9 Sensor and	1049E-2a
	Sensor Adapter or	1049E-2b
	Lambda LSU 4.2 Sensor or	1042A-2
	NTK TL UEGO Sensor	1001A-2
3.	Wiring Harness, 6m or	1002A-3a[1]
	Wiring Harness, 3m or	1002A-3b[1]
	Wiring Harness, 1m	1002A-3c[1]
4.	SMB/PC Cable, 2m (AFM1500)	1500A-16
5.	SMB/PWR Cable, 300mm (AFM1500)	1500A-17
6.	Calibration Screwdriver	2400E-35
7.	Sensor Mounting Boss and Plug (M18X1.5mm)	1000A-5
8.	Instruction Manual	1040A-6
9.	AFM1540.EXE Software Program Disk	1540A-7

[1] ECM offers custom harness solutions. Contact ECM for more information.

Important Operation Notes

1. Before installing the lambda sensor, apply a small amount of non-lead containing antiseize compound to its threads. Do not get the compound on the sensor's tip.

2. **Do not operate an engine for more than three minutes with the lambda sensor in the exhaust and the control module's power off. If the sensor is off in a running engine for a longer period, soot and water will condense in the sensor and may reduce its sensitivity.**

3. Do not use the lambda sensor in exhaust systems in which water is sprayed into the exhaust. Water striking the sensor may cause permanent sensor damage.

4. Do not put the lambda sensor in a heavily sooting or oil-burning engine.

5. Use of the lambda sensor with leaded fuels over time may reduce the sensitivity of the sensor.

6. Do not use the lambda sensor in a location where the temperature is greater than 950 deg. C (1742 deg. F) or if the pressure is not between 0.8 to 1.3 atm (23.9 to 38.9 inches Hg, 81 to 132 kPa).

7. Route and cable-tie the wiring harness away from hot or moving objects and ignition wires.

8. Do not remove or attach the lambda sensor from the instrument harness when the control module power is on.

9. Do not drop the lambda sensor onto a hard surface.

10. Do not expose the lambda sensor to flammable substances.

11. Do not attempt to wash the lambda sensor with any solvent or compressed air.

12. **Do not use the AFM with a sensor for which it is not programmed.**

How to Use

Hooking-up the AFM

Location of the Lambda Sensor

The lambda sensor should be located from 12" to 48" from the exhaust valve(s) of the engine. A location further from the engine may be used as long as it is at least ten times the exhaust pipe diameter upstream of the end of the exhaust system. For example, with a 2½" diameter exhaust pipe, the sensor should be at least 25" upstream of the end of the exhaust. The problem with locations less than ten diameters upstream is that reversion air may be trapped in the exhaust giving leaner than actual readings. This especially occurs at low exhaust flowrates (i.e. idle). Locating the lambda sensor far from the engine exposes the sensor to more liquid water during both start-up and normal operation and is not recommended.

When choosing a lambda sensor location, take into consideration engine movement, ground clearance, and wire harness routing.

Mount the lambda sensor in a location where the sensor's wires are pointing upward (9 o'clock to 3 o'clock). Do not mount the sensor where liquid inside the exhaust may collect in the sensor or its threads.

Install the lambda sensor by lightly coating its threads with a non-lead containing antiseize compound and tighten it to 30 ±3 ft-lbf (40 ±4 Nm). Attach the sensor to the wiring harness and route the harness to the control module. Use cable ties to keep the harness away from hot or moving objects and ignition wires.

Do not modify the wiring harness. Replace the wiring harness if it becomes damaged.

Installation of the Sensor Mounting Boss

The lambda sensor is mounted in the engine's exhaust by threading it into a M18X1.5mm boss that is cast, welded, or brazed onto the engine's exhaust pipe. This thread size is identical to that of most exhaust oxygen sensors (O_2 sensors) used in production automobiles with 3-way exhaust catalysts.

The sensor boss provided has a M18X1.5mm thread. To mount the boss, first drill a ¾" diameter hole in the desired location. Clean the area around the hole with a wire-brush and clamp the boss over the hole. Weld or braze the boss to the exhaust pipe. After the boss is attached to the exhaust, tap the treads to clean them and file the top of the boss to provide a flat surface for sealing.

When the lambda sensor is not being used, use the supplied plug (with some anti-seize) to plug the hole. Do not use the lambda sensor to plug the hole during engine operation when the control module is not powered-up.

Power

The AFM requires clean DC power of 11 to 28V at 1.4A (steady-state). During sensor warm-up, the requirements are approximately 5A for a period of up to 1 minute. A good car or motorcycle 12V battery can meet these specifications. An AC/DC power supply is available (P/N 1000A-7). The supplied wiring harness must be connected directly to the power source. Do not modify the wiring harness without first contacting ECM.

Warm-up

After powering-up the AFM, it will take approximately 30 seconds for the control module to bring the lambda sensor to its operating temperature. It is okay to have the engine running during this period. In fact it is recommended that a cold engine be started for a short period (i.e. one minute) before the AFM is powered-up. The reason for this is to allow any condensed water to be cleared from the exhaust system. Any liquid can thermally shock the lambda sensor.

For applications where the sensor is mounted in a tailpipe probe, it is especially important to make sure that all condensed water is out of the tailpipe before the tailpipe probe is inserted into the exhaust.

Analog Output

The AFM has a 0V to 5V linearized output suitable for input into a data acquisition or engine control system. The analog output is available from the female BNC connector on the wiring harness. For the AFM1040 only, the shell of the connector is signal ground and it is electrically connected to the power source ground.

The measurement range for gasoline is 8.0 to 18.0 AFR. The relationship between the analog output (Vout) and the AFR (for gasoline[1]) is:

$$\mathbf{AFR = 2.0 \times Vout + 8.0 \text{ (gasoline only)}} \qquad \text{[Equation 1]}$$

For example, if Vout is 1.0 V then the AFR is 10.

When the AFM is first turned on, the output passes through a sequence of three voltages. Each voltage is held for five seconds. For the AFM1040, these three voltages are 0.0V, 3.28V and 5.0V. For the AFM1540, the three voltages are 0.5V, 3.28V and 4.5V. The purpose of this sequence is to verify correct electrical connection and signal conversion with the AFM and the data receiving device.

[1] Assumes fuel H:C ratio of 1.85. For other fuels see the "Fuel Type Compensation" section.

Changing Sensor Type (AFM1540 Only)

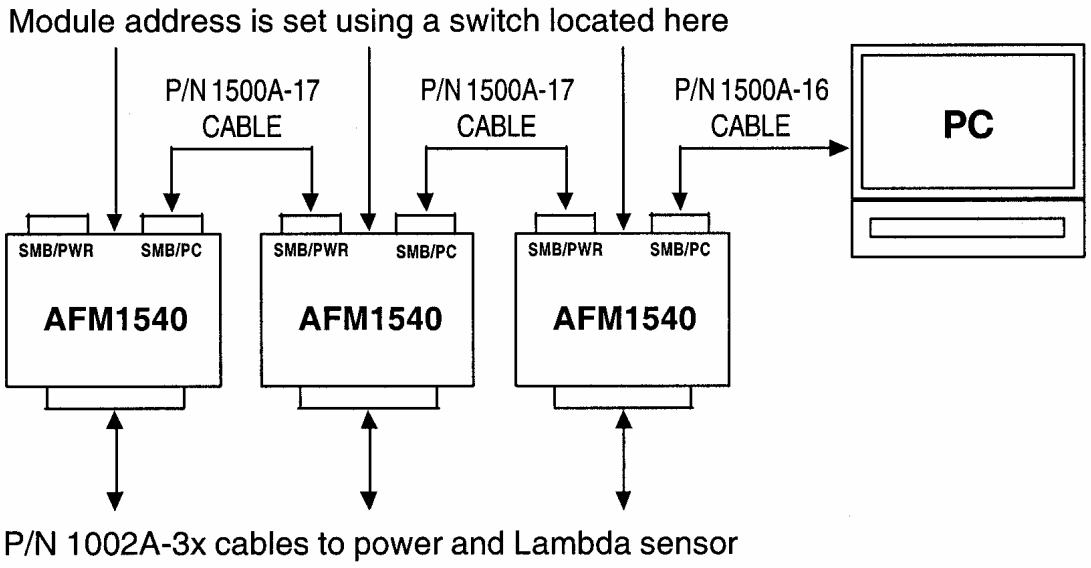
AFMs are delivered programmed to use one of the following sensors: Bosch LSU 4.9, LSU 4.2, or NTK UEGO. This is indicated on the AFM's label. The AFM1540 can be user-reprogrammed to use any one of these sensors. PC software routine AFM1540.EXE is supplied with the AFM1540 to facilitate this. Refer to the Supplementary Information section at the end of this manual for more information.

SMB Interface (Serial Measurement Bus, AFM1540 Only)

The AFM1540 has a SMB interface allowing serial communication with as many as 16 AFM1540 modules using a single RS-232 type serial port from a computer. Using the SMB interface, AFR, FAR (the inverse of AFR), λ, $\%O_2$, and module status can be read from each AFM1540 module. The interface supports auto-detection of modules.

The figure below shows an example with three AFM1540 modules connected to a computer (here a PC) using the SMB interface. Each module must have a unique address between 0 and Fh (i.e. 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F) that is set using a switch located between the two SMB connectors on the AFM1540.

Cable part number 1500A-16 connects the PC to the SMB/PC port of any one of the AFM1540 modules (i.e. it does not have to be the module with address 0), and subsequent AFM1540 modules are daisy-chained using part number 1500A-17 cables.



Communication is 38400 baud, 1 stop bit, 8 data bits, 1 stop bit and no parity.

The computer sends a one byte message. The high nibble contains the module address (0 to Fh) and the low nibble contains the command (0 to Fh).

The AFM1540 module addressed responds (within 1 ms max.) with the byte of data requested.

The command from the PC to the AFM1540 modules and the conversion formulas for the data from the AFM1540 modules to the PC are given in the following table. The state diagram for SMB communication is at the back of this instruction manual.

COMMAND	DESCRIPTION	RANGE	FORMULA
0h	Enter Command Mode		See Command Mode and Device Identification Sections
1h	8 bit λ	0.744 to 1.235	λ = (Data Byte + 186)/250
2h	16 bit λ High Byte	0.549 to 1.235	λ = (High Byte*256 + Low Byte)/1000
3h	16 bit λ Low Byte		
4h	16 bit Ri High Byte	0 to 400 Ω	Ri = (High Byte*256 + Low Byte)/10
5h	16 bit Ri Low Byte		
6h	16 bit $\%O_2$ High Byte	0.0 to 4.03	$\%O_2$ = (High Byte*256 + Low Byte)/100
7h	16 bit $\%O_2$ Low Byte		
8h	16 bit AFR High Byte	8.0 to 18.0	AFR = (High Byte*256 + Low Byte)/100
9h	16 bit AFR Low Byte		
Ah	16 bit FAR High Byte	0.055 to 0.125	FAR = (High Byte*256 + Low Byte)/10000
Bh	16 bit FAR Low Byte		
Ch	16 bit Ip High Byte	-2849 to 492 μA	Ip = (High Byte*256 + Low Byte)/10
Dh	16 bit Ip Low Byte		
Eh	N/A		AFM1540 Status Code (See table below)
Fh	N/A		

PWR (Green) LED	ERR (Red) LED FLASH CODE	STATUS CODE	CONDITION
ON	OFF	0	Data valid/Sensor OK
OFF	1	1	Sensor not connected or heater open
OFF	2	2	Heater short
OFF	3	3	Power supply voltage out of range
OFF	4, 5, or 6	4, 5, or 6	Sensor damaged
Flashing	OFF	8	30 second warm-up
ON	ON	9	EE Fault
ON	ON	10	Command Mode

Command Mode

Command Mode is used to auto-detect AFM1540 and F/A1540 modules on the SMB bus.

After the reception of command XXXX 0000 (where XXXX = module address) the module switches into Command Mode and waits for a second byte. Upon entering Command Mode, wait 30 ms minimum before issuing commands. **The sensor is powered off when the unit is in Command Mode.** The module remains waiting until a second byte with the correct device number in the high-nibble is received.

1st BYTE	2nd BYTE	COMMAND NO.	COMMAND
XXXX 0000	XXXX 0000	0	Stay in Command Mode
XXXX 0000	XXXX 0001	1	Device Identification (See Below)
XXXX 0000	XXXX 0010	2	Not Used
….	….	….	….
XXXX 0000	XXXX 1111	15	Exit Command Mode

Device Identification

In response to the DEVICE IDENTIFICATION command, the module sends back 6 bytes (including a check sum): 0x00, 0x02, 0x18, 0x0C, 0x00, 0xDA. This will identify the module as an ETAS LA3 to INCA software.

Calibration

Calibration of the AFM and the lambda sensor can be easily performed using air.

To bring the system into calibration, put the sensor in air and adjust the calibration potentiometer (CAL POT) on the control module using the calibration screwdriver provided. First turn the potentiometer counter-clockwise until the CAL LED (yellow) is off, then turn the potentiometer slowly clockwise until the CAL LED just lights. If the CAL POT cannot be turned to where the CAL LED is off then the sensor is bad.

For best accuracy, the AFM and lambda sensor should be on for at least 20 minutes prior to calibration.

For best accuracy, the lambda sensor should be held with its tip pointing down in still air during calibration. Calibrating with the sensor in an “off” engine is not recommended due to the possibility of residual exhaust gases remaining in the exhaust system.

Fuel Type Compensation

The standard AFM output is for gasoline (measurement range of 8.0 to 18.0 AFR) with a fuel H:C ratio of 1.85 and an O:C ratio of zero. If a fuel of a different composition is used, the AFR measurement range will be different. The analog output formulas and AFR measurement range for commonly used fuels are given in the table below:

Fuel Type	AFR vs. Vout	AFR Measurement Range
Methanol (race car "alcohol")	AFR = 0.888 x Vout + 3.55	3.55 to 7.99
Ethanol (grain alcohol)	AFR = 1.236 x Vout + 4.94	4.94 to 11.12
M85	AFR = 1.039 x Vout + 4.16	4.16 to 9.36
E85	AFR = 1.340 x Vout + 5.36	5.36 to 12.06
Natural Gas (CH_4)	AFR = 2.366 x Vout + 9.46	9.46 to 21.29

For fuel types not given in the table above, and for AFR read via the SMB, Equation 2 can be used to compensate (i.e. correct) the AFM's output.

AFRcorr = [(2.368 x (m - 2p + 4)) / (m + 16p + 12)] x AFRmeas [Equation 2]

where: **AFRcorr** is the AFR for the fuel of H:C=m and O:C=p composition.
AFRmeas is the AFR output by the AFM (i.e. 8.0 to 18.0 AFR).
$m > (2p - 4)$.

Pressure Compensation

All wide-range exhaust sensors have a pressure sensitivity. Errors occur when the sensor is operated at pressures different from the pressure at which it was calibrated. Changes in pressure come about from changes in weather, altitude changes, and engine backpressure. There is no sensitivity to pressure at stoichiometric ($\lambda = 1$) conditions. The sensitivity gets greater the further from stoichiometric the engine is operated. Increases in pressure make the sensor read further from stoichiometric (i.e. if lean, reads leaner, if rich, reads richer). For example, an increase in exhaust pressure of 127 mmHg above the calibration pressure (which would result from calibrating at 1 mile above sea level and then driving down to sea level) would make a 12.57 AFR engine read 12.50 or a 16.90 AFR engine read 17.00.

If Equation 2 (fuel type compensation) and Equation 3 (pressure compensation) are to both to be used, apply Equation 3 first, then Equation 2.

Pressure Compensation Equation for AFR

AFR(corrected) = (AFR(measured) + B x P) / (1 + C x P) [Equation 3a]

where: AFR(corrected) = the AFR corrected for exhaust pressure.
AFR(measured) = the AFR output by the AFM.
B = 0.00398 (LSU 4.2), 0.00395 (LSU 4.9), 0.009140 (NTK) rich
B = 0.00471 (LSU 4.2), 0.00453 (LSU 4.9), 0.012100 (NTK) lean
C = 0.000273 (LSU 4.2), 0.000271 (LSU 4.9), 0.000627 (NTK) rich
C = 0.000323 (LSU 4.2), 0.000311 (LSU 4.9), 0.000830 (NTK) lean
P = the exhaust pressure in mmHg above the pressure at which the sensor was calibrated (using the CAL POT on the AFM while the sensor is held in air). Equation 3a is valid for -150 mmHg < P < 300 mmHg.

Pressure Compensation Equation for Lambda

Lambda(corrected) = (Lambda(measured) + B x P) / (1 + B x P) [Equation 3b]

where: Lambda(corrected) = the Lambda corrected for exhaust pressure.
Lambda(measured) = the Lambda output by the AFM.
B = 0.000273 (LSU 4.2), 0.000271 (LSU 4.9), 0.000627 (NTK) rich
B = 0.000323 (LSU 4.2), 0.000311 (LSU 4.9), 0.000830 (NTK) lean
P = the exhaust pressure in mmHg above the pressure at which the sensor was calibrated (using the CAL POT on the AFM while the sensor is held in air). Equation 3b is valid for -150 mmHg < P < 300 mmHg.

Pressure Compensation Equation for $\%O_2$

$\%O_2$(corrected) = $\%O_2$(measured) / [1.0 + B x P] [Equation 3c]

where: $\%O_2$ (corrected) = the $\%O_2$ corrected for exhaust pressure.
$\%O_2$ (measured) = the $\%O_2$ output by the AFM.
B = 0.000323 (LSU 4.2), 0.000311 (LSU 4.9), 0.000830 (NTK)
P = the exhaust pressure in mmHg above the pressure at which the sensor was calibrated (using the CAL POT on the AFM while the sensor is held in air). Equation 3c is valid for -150 mmHg < P < 300 mmHg.

Specifications and Limits

Measurement Range and Accuracy

Range: 8 to 18 AFR (gasoline)[1] (Analog Output and SMB)
0.055 to 0.125 FAR, 0.549 to 1.235 λ, 0.0 to 4.0 %O_2 (SMB Only)
Accuracy: 1.5%

Exhaust Operating Limits

Maximum Exhaust Gas Temperature: 950 deg. C, 1742 deg. F.
Exhaust Gas Pressure Range: 0.8 - 1.7 atm (gauge).

Sensor Installation

Thread Size: M18X1.5mm. Lightly coat with non-lead containing antiseize compound.
Hex Size: 22mm.
Tightening Torque: 30 ±3 ft-lbf, 40 ±4 Nm.

The lambda sensor's thread size is identical to that of most O_2 sensors used in production vehicles.

Output Specifications and Limits

Analog Output:

- 0V at 8.0:1 AFR (gasoline)[1]
- 5V at 18.0:1 AFR (gasoline)[1]
- AFR = 2.0 x V + 8.0 (gasoline)[1]
- λ = 0.137 x V + 0.549
- Output Impedance: 500 Ohm
- Output Connector: Female BNC, Signal = Center, Ground = Shell

[1] Assumes fuel H:C ratio of 1.85. For other fuels see the "Fuel Type Compensation" section.

SMB Interface (Serial Measurement Bus, AFM1540 Only):

- AFR, FAR, λ, %O2, and Module Status Output
- Each Module can be assigned an address from 0h to Fh using a switch on the side of the module
- Auto-detect feature for Device Identification
- 38400 baud, 1 Start Bit, 8 Data Bits, No parity
- For Communication Protocol, See SMB Interface Section
- SMB Ground and Power are Isolated (±200V max)

SMB/PC Cable Terminal Assignments (AFM1540 Only):
(Cable from PC to SMB/PC Port on AFM1540 Module, 6ft., P/N 1500A-16)

DB9 Female (to PC) Terminal Number	DB9 Male (to Module) Terminal Number
2 (Rx)	1
3 (Tx)	2
5 (Gnd)	6

SMB/PC Cable Terminal Assignments (AFM1540 Only):
(Cable from SMB/PWR to SMB/PC ports on AFM1540 Modules, 1ft., P/N 1500A-17)

DB9 Male (to Module) Terminal Number	DB9 Male (to Module) Terminal Number
1	2
2	1
6	6
3	3
7	7
8	8
4	4
5	5
9	9

General Information

Power: 11 to 28 VDC at 5A (surge), 1.4A (continuous)

Fuse: Internal, automatically resetable

Dimensions: 4" x 3.5" x 1", 102mm x 89mm x 25mm (W x H x D)

Weight: 5.6 oz., 160 gm.

Troubleshooting

If the PWR (Green) LED on the side of the unit is on, all is okay.

If the PWR (Green) LED on the side of the unit is flashing continuously, the unit is warming up. The sensor requires approximately 30 seconds of warm-up time after the unit is turned on.

If the ERR (Red) LED is flashing (see table on page 7), the lambda sensor is bad. Of course, this will also occur if the sensor is not connected.

Sometimes one or more of these codes will occur within 1 minute of power-up. This is okay as long as they do not remain active after 1 minute.

If the ERR (Red) LED is flashing 3 times per second, the battery voltage is either too low (less than 11 V) or too high (greater than 28 V). If this occurs, immediately stop the engine and supply the correct battery voltage to the control module.

If the CAL POT cannot be turned counterclockwise to where the CAL (Yellow) LED is off then the sensor is bad.

If the AFM outputs erroneous values, one of three conditions exists:

1. The unit is being confused by noisy power or operating in an electrically noisy environment. In some situations, a timing light might create a noise problem. Keeping the control module and its wiring harness away from the engine's ignition wires will help avoid this source of electrical noise.

2. For the AFM1040 only, the ground wire on the wiring harness is not attached directly to the ground at the vehicle's battery. If you connect a single wire from the wiring harness ground to the vehicle's battery, a large voltage drop will occur across that wire and cause the analog output ground at the BNC connector to be elevated above battery ground. And since battery ground is often the engine's data acquisition ground, if you hook the analog output ground at the BNC connector to the ground at the data acquisition system then you will cause a current loop through the ground of the data acquisition system to the vehicle battery.

3. The AFM must be returned to the factory for repair. There are no user-repairable components inside the control module. The warranty is void if the control module is opened or wiring harness is modified. Contact ECM before returning the AFM to the factory.

Safety Warnings

In the installation and use of this product, comply with the National Electrical Code and any other applicable Federal, State, or local safety codes.

Always wear eye protection when working near engines, vehicles, or machinery.

During installation, turn off the power and the engine and take all other necessary precautions to prevent injury, property loss, and equipment damage. Do not apply power or start the engine until all wiring is completed.

Never work on a running engine.

When installing the AFM's cabling and sensor on a stopped engine, it is best to think-out your moves before you make them.

Route and cable-tie all cables away from hot, moving, sharp, high energy (spark), and caustic objects.

Take into consideration the movement of the engine, chassis, and wind buffeting when instrumenting the engine.

Clear tools away from the engine before starting.

Operate the engine only in a well ventilated area and never when you or one of your co-workers is tired.

One measure of professionalism is how much you and your co-workers can accomplish without an injury. Always be at your professional best. Think and act with safety in mind.

Warranty and Disclaimers

WARRANTY

The products described in this manual, with the exception of the lambda sensor, are warranted to be free from defects in material and workmanship for a period of one year from the date of shipment to the buyer. Within the one year warranty period, we shall at our option replace such items or reimburse the customer the original price of such items which are returned to us with shipping charges prepaid and which are determined by us to be defective. This warranty does not apply to any item which has been subjected to misuse, negligence or accident; or misapplied; or modified; or improperly installed.

The lambda sensor is considered an expendable part and as such cannot be covered by a warranty.

This warranty comprises the sole and entire warranty pertaining to the items provided hereunder. Seller makes no other warranty, guarantee, or representation of any kind whatsoever. All other warranties, including but not limited to merchantability and fitness for purpose, whether express, implied, or arising by operation of law, trade usage, or course of dealing are hereby disclaimed.

The warranty is void if the control module is opened or the wiring harness is modified.

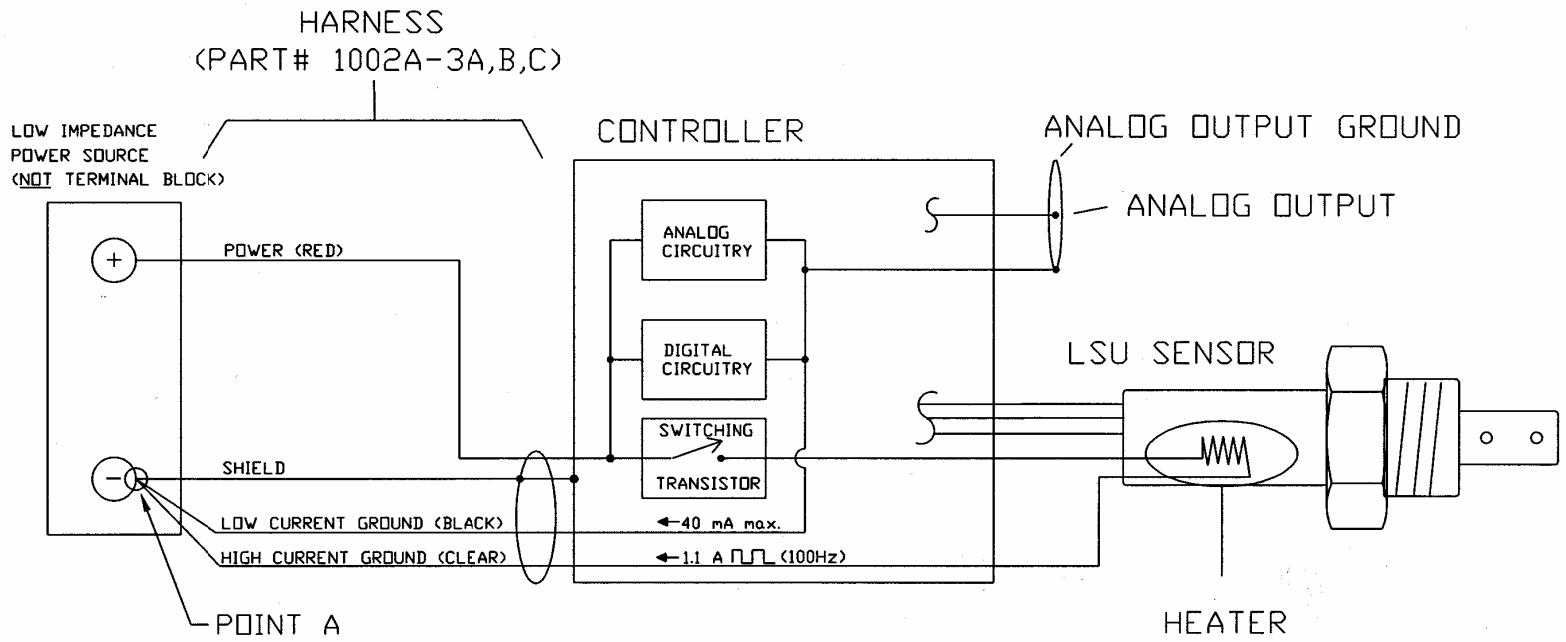
LIMITATION OF REMEDY

Seller's liability arising from or in any way connected with the items sold and/or services provided shall be limited exclusively to repair or replacement of the items sold or refund of the purchase price paid by buyer, at seller's sole option. In no event shall seller be liable for any incidental, consequential or special damages of any kind or nature whatsoever, including but not limited to lost profits arising from or in any way connected with items sold and/or services provided to buyer, whether alleged to arise from breach of contract, express or implied warranty, or in tort, including without limitation, negligence, failure to warn or strict liability. In no event shall the company's liability to buyer arising out of or relating to the sale of any product or service exceed the purchase price paid by buyer to the company for such product or service.

PRODUCT CHANGES

We reserve the right to discontinue a particular product or to make technical design changes at any time without notice.

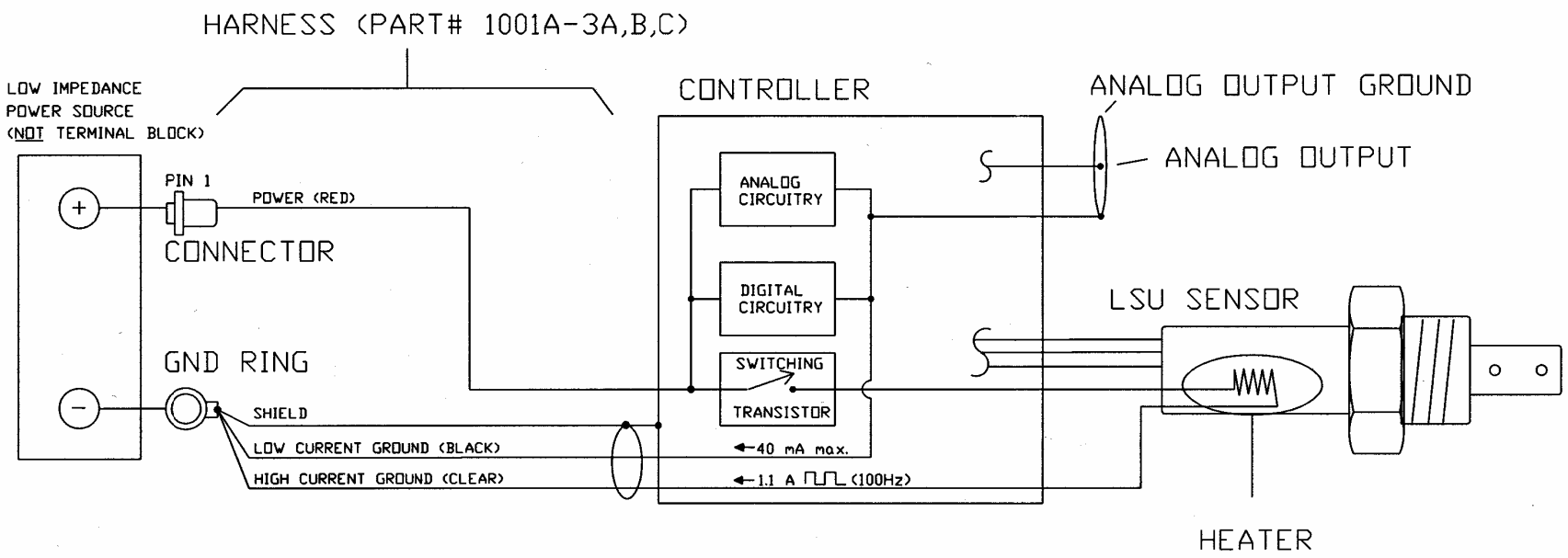
POWER WIRING FOR AFM1040-F/A1040



NOTES:

1. TWO GROUND WIRES ARE USED. ONE TO CLOSE THE CURRENT LOOP ON THE SENSOR HEATER AND ONE TO CLOSE THE LOOP ON THE ELECTRONIC CIRCUITRY. IF YOU RUN GROUNDS ON SAME WIRE, YOU WILL GET NOISE IN OUTPUT.
2. DO NOT REWIRE TO MAKE SINGLE WIRE FROM POINT A TO ACTUAL BATTERY. IF YOU DO THEN YOU WILL GET A LARGE VOLTAGE POTENTIAL BETWEEN THE ANALOG OUTPUT GROUND AND BATTERY.
3. IF YOU WIRE AS SHOWN ABOVE, VOLTAGE POTENTIAL BETWEEN ANALOG OUTPUT GROUND AND BATTERY GROUND WILL BE SMALL (<0.002 VOLTS).
4. IN SOME APPLICATIONS, CUTTING LOW CURRENT GROUND (BLACK) AT GROUND RING AND CLOSING GROUND VIA ANALOG OUTPUT GROUND MAY IMPROVE NOISE IMMUNITY OF SYSTEM. FOR THIS CASE, THE GROUND OF THE EQUIPMENT ATTACHED TO THE ANALOG OUTPUT MUST ITSELF BE CONNECTED TO BATTERY GROUND.

OPTIONAL POWER WIRING FOR AFM1040-F/A1040



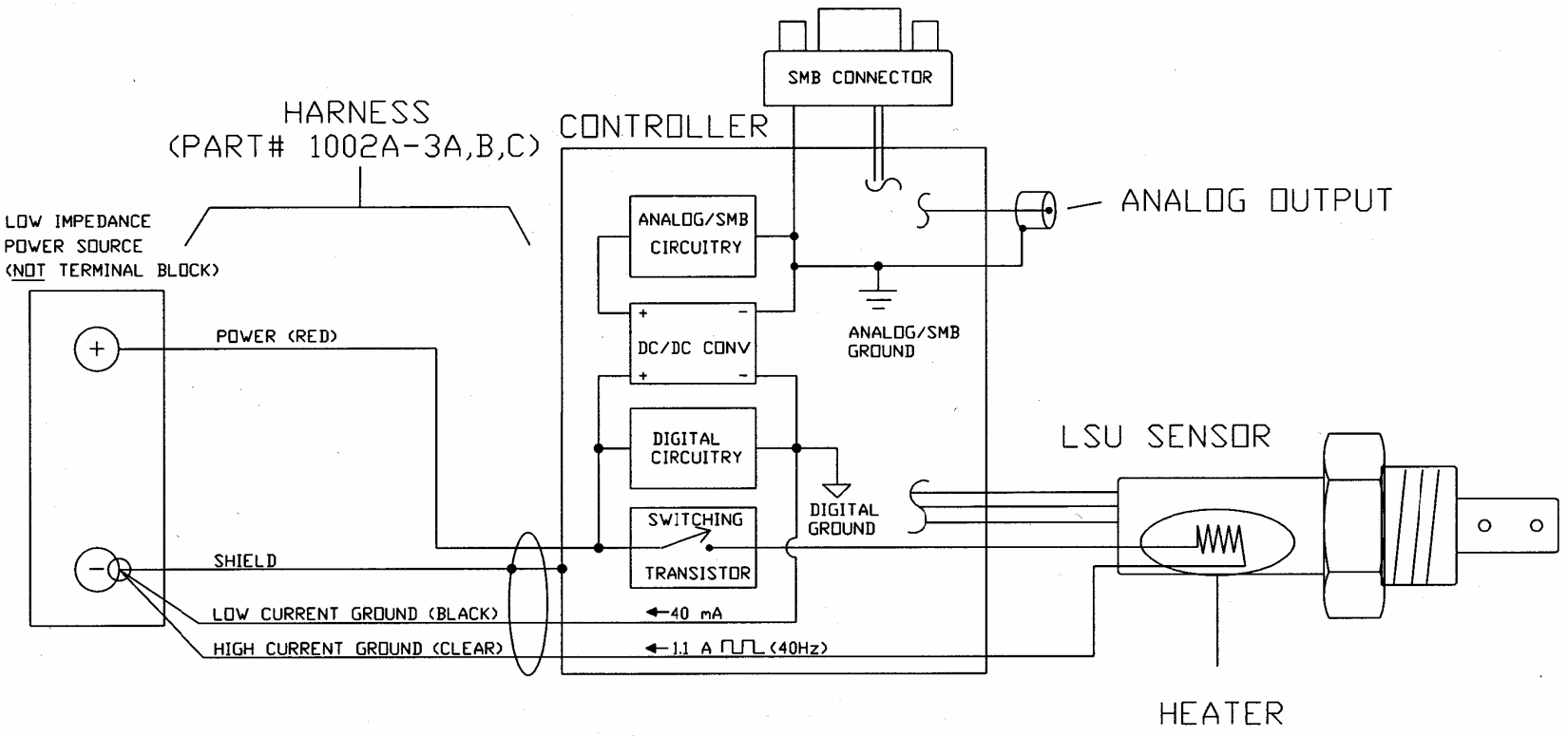
NOTES:

1. TWO GROUND WIRES ARE USED. ONE TO CLOSE THE CURRENT LOOP ON THE SENSOR HEATER AND ONE TO CLOSE THE LOOP ON THE ELECTRONIC CIRCUITRY. IF YOU RUN GROUNDS ON SAME WIRE, YOU WILL GET NOISE IN OUTPUT.
2. WIRES FROM CONNECTOR AND GROUND RING TO BATTERY MUST BE BIG AND AS SHORT AS POSSIBLE.
3. IN SOME APPLICATIONS, CUTTING LOW CURRENT GROUND WIRE (BLACK) AT GROUND RING AND CLOSING GROUND VIA ANALOG OUTPUT CONNECTOR (SHELL OF BNC) MAY IMPROVE NOISE IMMUNITY OF SYSTEM. FOR THIS CASE, THE GROUND OF THE EQUIPMENT ATTACHED TO THE ANALOG OUTPUT MUST ITSELF BE ATTACHED TO BATTERY GROUND.
4. CONNECTOR IS AMP 206429-1 (PLUG), 206062-1 (CLAMP), 66099-4 (PIN).
5. RING IS SOLISTRAND 33220 (3/8", 12-10 AWG).

AFM1040_OPT.DWG

408-734-3433

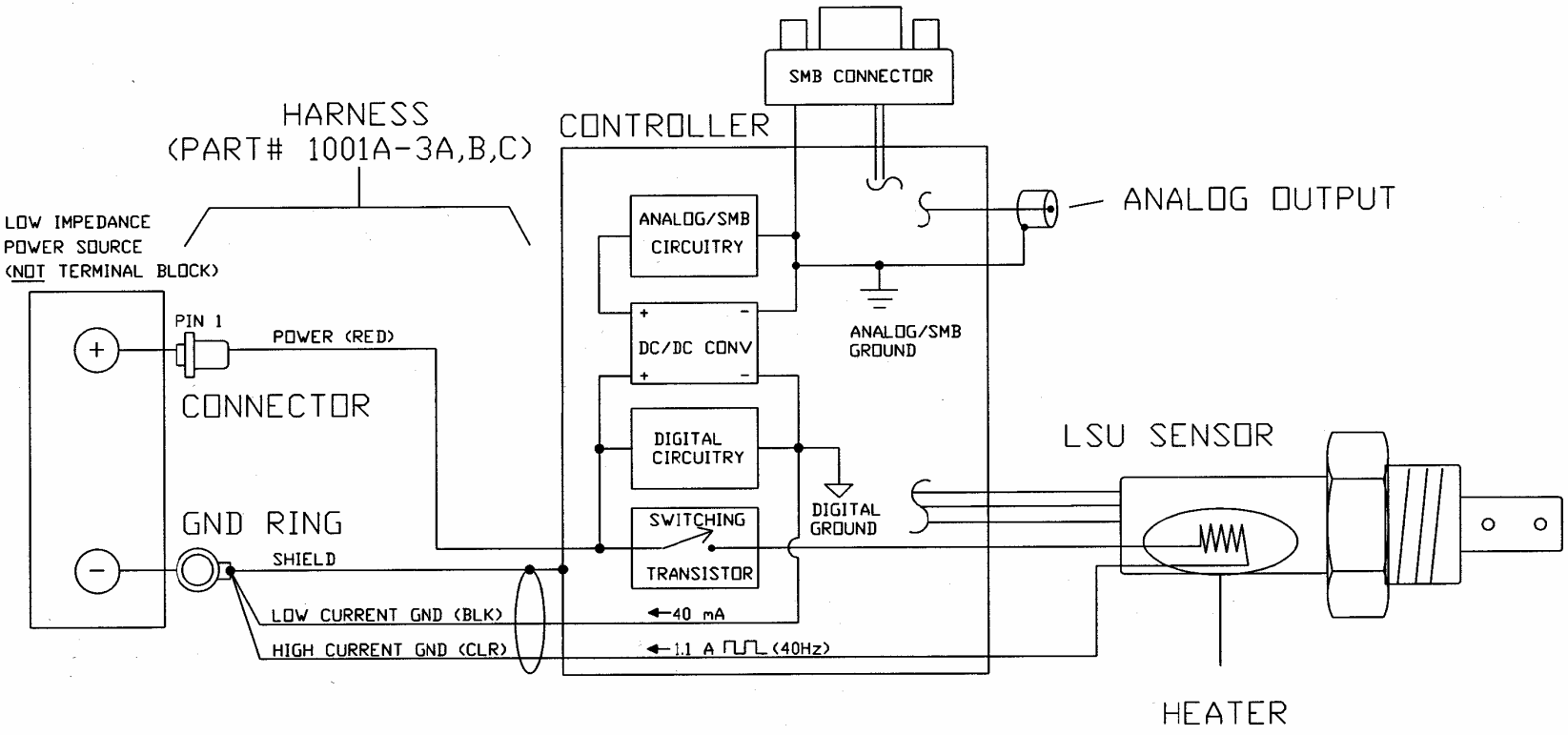
POWER WIRING FOR AFM1540-F/A1540



NOTES:

1. TWO CURRENT CARRYING GROUND WIRES ARE USED: ONE TO CLOSE THE LOOP ON THE SENSOR HEATER AND ONE TO CLOSE THE LOOP ON THE ELECTRONIC CIRCUITRY.
2. WIRES FROM CONNECTOR AND GND RING TO POWER SOURCE MUST BE BIG AND AS SHORT AS POSSIBLE.
3. ANALOG/SMB GROUND ISOLATED FROM DIGITAL GROUND (+/- 200V MAX).

OPTIONAL POWER WIRING FOR AFM1540-F/A1540



NOTES:

1. TWO CURRENT CARRYING GROUND WIRES ARE USED. ONE TO CLOSE THE LOOP ON THE SENSOR HEATER AND ONE TO CLOSE THE LOOP ON THE ELECTRONIC CIRCUITRY.
2. WIRES FROM CONNECTOR AND GND RING TO POWER SOURCE MUST BE BIG AND AS SHORT AS POSSIBLE.
3. ANALOG/SMB GROUND ISOLATED FROM DIGITAL GROUND (+/- 200V MAX).
4. CONNECTOR PARTS: AMP 206429-1 (PLUG), 206062-1 (CLAMP), 66099-4 (PIN).
5. RING IS SOLISTRAND 33220 (3/8", 10-12 AWG).

AFM1540_OPT.DWG

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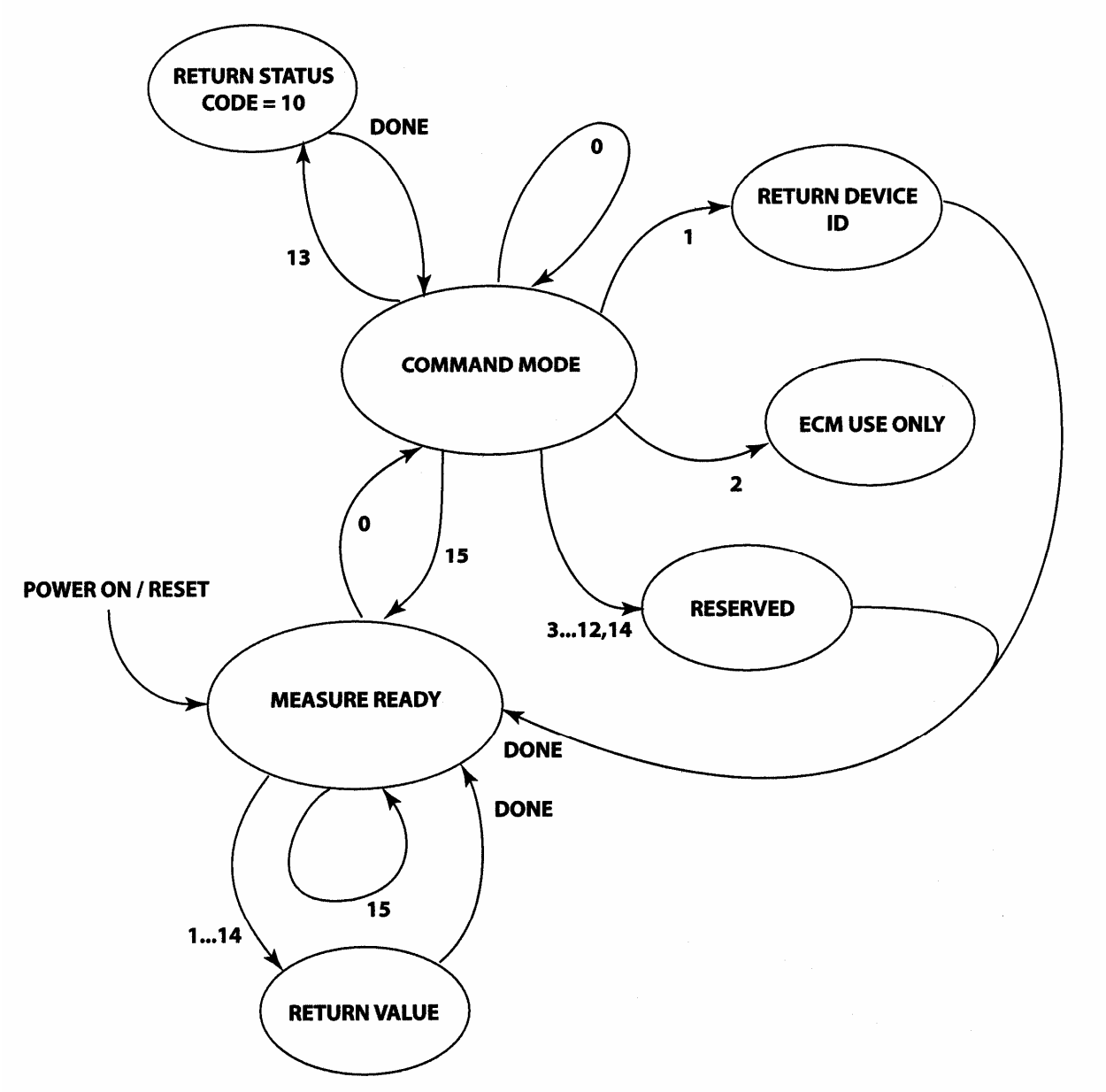
State Diagram for SMB Communication



AFM1540.EXE 1.2 Eeprom Programming Software (AFM1540 Only)

AFMs are delivered programmed to use one of the following sensors: Bosch LSU 4.9, LSU 4.2, or NTK UEGO. This is indicated on the AFM's label. The AFM1540 can be user-reprogrammed to use any one of these sensors. PC software routine AFM1540.EXE is supplied with the AFM1540 to facilitate this. After reprogramming the AFM1540 to use another sensor, indicate on the AFM's label which sensor it is programmed for.

*** Using the wrong programming with the wrong sensor will result in sensor damage. ***

Minimum system requirements:

- Windows 95 or higher
- Serial communication port (COM1 with DB9 connector)

Installing the software:

- Copy all files on the floppy disk to a folder (all files must reside in the same folder)

Operation:

1. Close all active program windows on the PC.

2. Connect the SMB/PC cable (P/N 1500A-16) from the SMB/PC connector on the AFM to the COM1 port on the PC. Only one AFM can be programmed at a time. Do not connect other AFM units using the SMB/PWR cables to the AFM being programmed. A sensor does not have to be attached and ignore any lights on the AFM.

3. Turn the AFM1540's power switch "off" and connect power (12 to 28 VDC) to the AFM1540's wiring harness (P/N 1002A-3x).

4. Double click on the AFM1540 icon ("AFM1540").

5. **Carefully follow the program instructions. There are several steps.**

6. The program requires the user enter a .txt filename as follows:

   lsu49.txt (to program the AFM1540 for a Bosch LSU 4.9 sensor)
   lsu42.txt (to program the AFM1540 for a Bosch LSU 4.2 sensor)
   tl6312.txt (to program the AFM1540 for an NTK TL6312 sensor)

7. When finished programming, close the window.

Typical Output on PC Monitor:

```
TL6312.TXT          FILE       AFM15          FIRMWARE REV = 1.02
                    DATA       DATA
 1     E_REV          4          4
 2     E_XXX          0          0
 3     E_LAM        170        170
 4     E_LAB         32         32
 5     E_VH         185        185
 6     E_VHIN        80         80
 7     E_RMP          4          4
 8     E_VHPK       125        125
 9     E_VBAT       132        132
10     E_VBL         88         88
11     E_VBH        225        225
12     E_SUBT         0          0
13     E_AFM        127        127
14     E_AFB        138        138
15     E_FAM        120        120
16     E_FAB        147        147
17     E_0            0          0
18     E_1            0          0
19     E_2            0          0
20     E_3            0          0
21     E_4            0          0
22     E_5            0          0
23     E_6            0          0
24     E_7            0          0
25     E_8            0          0
26     E_9            0          0
27     E_A            0          0
28     E_B            0          0
29     E_C            0          0
30     E_D            0          0
31     E_E            0          0
       CHECKSUM      41         41

PROGRAMMING SUCCESSFUL, PRESS <Enter> TO RESTART, <Q> TO QUIT
```

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